

SCIENCE AND TECHNOLOGY IN DEVELOPMENT

- ✧ Atomic and Nuclear Physics
- ✧ Electronics and Communication
- ✧ Nanotechnology
- ✧ Electrochemical Cells
- ✧ Polymers
- ✧ Nutrition
- ✧ Antibiotics
- ✧ Biotechnology and Applications
- ✧ Other Applications of Biotechnology
- ✧ Advanced Reproductive Techniques
- ✧ Contributions of Scientists from Tamil Nadu
- ✧ Computer Fundamentals
- ✧ Major Scientific Achievements of India

ATOMIC AND NUCLEAR PHYSICS

- ➡ Atomic and Nuclear Physics studies the structure, behavior, and interactions of atoms and nuclei. Atomic physics explores electrons and energy levels, while nuclear physics focuses on the nucleus, radioactivity, and nuclear reactions. The field evolved through key discoveries—Dalton's atomic theory (1808), Thomson's electron (1897), Rutherford's nuclear model (1911), Bohr's quantum atom (1913), and Chadwick's neutron (1932). Milestones include radioactivity (Becquerel, Curies), Einstein's $E=mc^2$, nuclear fission, and the development of nuclear power and medicine.
- ➡ In India, Homi J. Bhabha pioneered atomic research, leading to the creation of the Bhabha Atomic Research Centre (BARC) and the Atomic Energy Commission (AEC) in 1948. India developed its own nuclear reactors, starting with Apsara (1956), Asia's first research reactor. The Department of Atomic Energy (DAE) oversees nuclear regulation, power generation, and safety. The Atomic Energy Regulatory Board (AERB) ensures radiation protection and compliance with safety norms.
- ➡ India is now a recognized nuclear power, using nuclear technology for electricity generation, agriculture, medicine, and space research. With initiatives like "Make in India" and international collaborations, the country continues to advance in peaceful and sustainable nuclear development.

Radioactivity

Discovery of Radioactivity

- ➡ Henri Becquerel accidentally discovered radioactivity in 1896. Without knowing, he stored uranium compound and photographic plate together and after several hours he had observed that the photographic plate was exposed to radiation. He explained that he could reproduce the same effect whenever he placed uranium near a photographic film. Thus, uranium radiated something that could affect a photographic plate. This phenomenon was called a **Radioactivity**. He identified that uranium was a radioactive element.
- ➡ Two years later, (i.e., in 1898), the polish physicist **Marie Curie** and her husband **Pierre Curie** detected radioactivity in '**Pitchblende**', a tiny black substance which is known as an ore of uranium. Later they observed that pure uranium is more intense in radiation. Also, it was found that the **Pitchblende** had less concentration of uranium. Thus, it is evident that some other new substance was present in Pitchblende. After segregating this new substance combined in pitchblende, they discovered that it had unknown chemical properties and it also emitted radiations spontaneously like uranium. They named

this new substance as '**Radium**'. It is also important to know that radioactive elements emit harmful radioactive radiations. They are alpha, beta and gamma rays.

Uranium, named after the planet Uranus, was discovered by Martin Klaproth, a German chemist in a mineral called pitchblende.

Definition of Radioactivity

- ➡ Radioactivity is defined as the process in which unstable atomic nuclei loses energy by emitting radiation in the form of particles or electromagnetic waves. Nuclear instability occur when the nucleus experiences the intense conflict between the two strongest force in nature.
- ➡ The phenomenon of nuclear decay of certain elements with the emission of radiations like alpha, beta and gamma rays is called '**radioactivity**' and the elements, which undergo this phenomenon are called '**radioactive elements**'.

Natural Radioactivity

- ➡ The elements such as uranium and radium undergo radioactivity and emit the radiations on their own without any human intervention. This phenomenon of spontaneous emission of radiation from certain elements on their own is called '**natural radioactivity**'.
- ➡ The elements whose atomic number is more than 83 undergo spontaneous radioactivity. Eg: uranium, radium, etc. There are only two elements, which have been identified as radioactive substances with atomic number less than 83. They are technetium (Tc) with atomic number 43 and promethium (Pm) with atomic number 61.

There have been 29 radioactive substances discovered so far. Most of them are rare earth metals and transition metals.

Artificial (or) Induced Radioactivity

- ➡ Not all nuclear reactions are spontaneous. The process of inducing previously stable material to make radioactive is known as '**artificial or induced or man-made radioactivity**'.
- ➡ The husband and wife team of Irene **Joliot-Curie** and Frederic **Joliot-Curie** discovered the method of induced radioactivity in 1934. Infact, this duo also shared the 1935 nobel prize in chemistry for this discovery.
- ➡ Artificial radioactivity is induced in certain lighter elements like boron, aluminium etc., by bombarding them with radiations such as '**alpha particles**' emitted

NANOTECHNOLOGY

- Nanotechnology is the science and engineering of manipulating matter at the atomic and molecular level, typically within the range of 1 to 100 nanometers. At this incredibly small scale, materials exhibit unique physical, chemical, and biological properties that differ significantly from their bulk forms. These nanoscale phenomena open vast opportunities for innovation across multiple fields, including medicine, electronics, energy, environment, and materials science.
- The concept of nanotechnology was first introduced by physicist Richard Feynman in 1959 in his famous lecture "There's Plenty of Room at the Bottom." The practical development began in the 1980s with the invention of the scanning tunneling microscope (STM), allowing scientists to visualize and manipulate individual atoms. Since then, nanotechnology has rapidly evolved, enabling breakthroughs like carbon nanotubes, graphene, quantum dots, and nanocomposites. Today, it is one of the most promising interdisciplinary technologies driving innovation in healthcare, energy storage, electronics, and sustainable materials.

India's Position in Nanotechnology

- India has recognized nanotechnology as a key emerging field and has made significant strides in research, development, and applications. The Government of India launched the Nano Mission in 2007 under the Department of Science and Technology (DST) to promote infrastructure, research funding, and collaboration between academia and industry. This mission supports projects in nanomaterials, nanomedicine, nanoelectronics, and environmental nanotechnology.
- Indian research institutions like the Indian Institute of Science (IISc) Bengaluru, IITs, and CSIR laboratories have made remarkable contributions in developing advanced nanomaterials and devices. The National Centre for Nanoscience and Nanotechnology (NCNN) at the University of Mumbai and the Centre for Nano Science and Engineering (CeNSE) at IISc are global leaders in nanotechnology research. India ranks among the top countries in nanoscience publications and patents, reflecting its growing research capability.
- The country is also integrating nanotechnology in strategic sectors—defense, agriculture, energy storage, and public health. For example, nanocoatings and nanofilters are being used in water purification, while nanomedicine is advancing drug delivery and diagnostics. The Indian government is encouraging industrial participation through public-private

partnerships, and policies are being framed to ensure safe and responsible use of nanomaterials.

Tamil Nadu's Role in Nanotechnology Development

- Tamil Nadu stands out as a major hub for nanotechnology research and innovation in India. The state has a strong network of universities, research centers, and industries working together to develop nano-based solutions. Institutions like IIT Madras, Anna University, VIT Vellore, and SRM Institute of Science and Technology have dedicated centers for nanoscience, nanomaterials, and nanoelectronics.
- The Nano Mission has supported several projects in Tamil Nadu focusing on nanocomposites, nanomedicine, and renewable energy applications. IIT Madras is a national leader in this field, conducting advanced research in nanofabrication, sensors, solar cells, and biomedical devices. The Centre for Nanoscience and Technology at Anna University plays a key role in training students and developing indigenous nanotechnology-based solutions for industries.
- Tamil Nadu also promotes collaboration between academia and industry through initiatives like TIDCO's (Tamil Nadu Industrial Development Corporation) support for high-tech manufacturing and research parks. With its focus on innovation and sustainability, the state aims to position itself as a nanotech manufacturing and research hub in South India, contributing to national growth in the high-tech sector.

Applications and Future Prospects

- Nanotechnology's applications are vast and transformative. In medicine, it is used for targeted drug delivery, imaging, and regenerative therapies. In electronics, nanomaterials enable smaller, faster, and more efficient semiconductors and sensors. In energy, nanotech improves battery performance, solar energy efficiency, and fuel cell technology. Environmental applications include pollution control, water purification, and waste treatment.
- As India and Tamil Nadu continue to invest in research, skill development, and ethical regulation, nanotechnology is poised to play a pivotal role in shaping a smarter, cleaner, and more sustainable future—fueling innovation across industries and improving quality of life at the atomic scale.

Key Features of Nanotechnology

- **Manipulation at Atomic and Molecular Level** – At nanoscale, scientists can arrange atoms and molecules precisely.

- ➡ **Unique Properties** – Nanomaterials may show enhanced strength, lighter weight, higher reactivity, improved electrical and thermal conductivity, and special optical characteristics.
- ➡ **Interdisciplinary Nature** – It combines physics, chemistry, biology, materials science, and engineering.

Uses of Nanotechnology

- ➡ **Medicine** – Targeted drug delivery, cancer treatment, diagnostic tools, regenerative medicine.
- ➡ **Electronics** – Development of smaller, faster, and more efficient semiconductors, transistors, and memory storage devices.
- ➡ **Energy** – Solar cells with higher efficiency, nanomaterials in batteries (like lithium-ion and supercapacitors).
- ➡ **Environment** – Water purification using nanofilters, pollution control, nanocatalysts for green chemistry.
- ➡ **Textiles and Consumer Goods** – Stain-resistant fabrics, scratch-proof coatings, cosmetics, and packaging.

Nano Fertilizers

- ➡ Agriculture forms the backbone of India's economy, and fertilizers play a vital role in improving crop yield and food security. Conventional fertilizers, though effective, often suffer from problems like low nutrient-use efficiency, soil degradation, and environmental pollution. To overcome these challenges, scientists have developed Nano Fertilizers, which represent an innovative application of nanotechnology in agriculture.
- ➡ Nano fertilizers are fertilizers engineered at the nanoscale (1–100 nm), where nutrients are either encapsulated, coated, or delivered using nanomaterials. They are designed to provide controlled and targeted release of nutrients to crops, thereby improving efficiency and reducing losses.

Examples include:

- ➡ Nano Urea (developed by IFFCO in India)
- ➡ Nano Zinc, Nano Iron, Nano Phosphorus fertilizers

Characteristics of Nano Fertilizers

- ➡ **Small size & large surface area** – Improves solubility and nutrient absorption.
- ➡ **Slow & controlled release** – Prevents leaching and volatilization.
- ➡ **Higher nutrient-use efficiency (NUE)** – Reduces the quantity of fertilizer needed.
- ➡ **Eco-friendly** – Minimizes soil and water pollution.
- ➡ **Targeted delivery** – Nutrients reach directly to plant cells.

Applications of Nano Fertilizers

- ➡ **Improved Crop Yield** – Nano urea boosts nitrogen absorption, enhancing growth.
- ➡ **Soil Health Management** – Reduces chemical load on soil compared to bulk fertilizers.

- ➡ **Sustainable Agriculture** – Supports precision farming and organic agriculture practices.
- ➡ **Stress Resistance** – Enhances crop resistance to drought, salinity, and pests.
- ➡ **Reduced Fertilizer Consumption** – For example, one 500 ml bottle of Nano Urea can replace a 45 kg bag of conventional urea.

Advantages of Nano Fertilizers

- ➡ Higher efficiency than traditional fertilizers.
- ➡ Cost-effective in the long run.
- ➡ Minimizes fertilizer waste.
- ➡ Reduces greenhouse gas emissions like N₂O from excess nitrogen use.
- ➡ Safer for environment and human health.

Challenges and Concerns

- ➡ Lack of awareness among farmers.
- ➡ Need for large-scale field trials.
- ➡ Regulatory and safety concerns about nanoparticles in soil and food chains.
- ➡ High initial cost of research and production.

Nano Fertilizers in India

India is a global pioneer in the adoption of nano fertilizers:

- ➡ Indian Farmers Fertilizer Cooperative (IFFCO) launched Nano Urea Liquid in 2021.
- ➡ Approved by the Department of Fertilizers (Govt. of India) under the Fertilizer Control Order.
- ➡ Being promoted under Atmanirbhar Bharat and Nano Mission.
- ➡ Field trials in states like Tamil Nadu, Gujarat, Punjab, and Uttar Pradesh show 8–10% yield increase and 50% reduction in conventional urea usage.

Nano fertilizers are a revolutionary step towards sustainable and smart agriculture. They promise to reduce dependency on bulk fertilizers, improve soil health, and protect the environment. With proper farmer training, large-scale adoption, and safety regulations, nano fertilizers could play a crucial role in ensuring food security and environmental sustainability in India and worldwide.

Nano Pesticides

- ➡ Agriculture depends heavily on pesticides to protect crops from pests, weeds, and diseases. However, conventional pesticides have several drawbacks: poor water solubility, rapid degradation, excessive use, and environmental contamination. To address these challenges, nanotechnology has been applied in agriculture to develop Nano Pesticides—a novel approach that enhances pesticide effectiveness while reducing harmful impacts.
- ➡ Nano pesticides are pesticides formulated using nanoparticles or nanocarriers to deliver active ingredients more efficiently. They are designed for

ELECTROCHEMICAL CELLS

Electrochemical cells are devices that convert chemical energy into electrical energy (or vice versa) through redox (oxidation-reduction) reactions. They form the foundation of batteries, fuel cells, and electrolysis processes that power countless modern technologies. In simple terms, an electrochemical cell consists of two electrodes (anode and cathode) and an electrolyte that allows the movement of ions. When a redox reaction occurs, electrons flow through an external circuit, generating an electric current.

There are two main types of electrochemical cells: galvanic (or voltaic) cells and electrolytic cells. Galvanic cells produce electrical energy from spontaneous chemical reactions. The classic example is the Daniell cell, which consists of a zinc anode and a copper cathode immersed in their respective sulfate solutions. Electrons flow from zinc (oxidized) to copper (reduced), producing an electric current. Electrolytic cells, on the other hand, use electrical energy to drive non-spontaneous reactions—such as electrolysis of water to produce hydrogen and oxygen gases.

Electrochemical cells play a vital role in daily life. They power portable devices such as mobile phones, laptops, and remote controls through batteries like dry cells, lithium-ion cells, and nickel-cadmium cells. Lead-acid batteries are used in automobiles, while fuel cells provide clean energy for space missions and electric vehicles. In industry, electrochemical processes are employed for metal refining, electroplating, and corrosion protection. Thus, these cells form the backbone of modern energy storage and conversion systems.

The working principle of electrochemical cells is based on oxidation at the anode and reduction at the cathode, with ions moving through the electrolyte to balance charge. The cell potential (voltage) depends on the difference in electrode potentials between the two half-cells. The Nernst equation is used to calculate this potential under different conditions, linking chemistry and physics in understanding energy transformations.

Advancements in electrochemistry have led to the development of rechargeable batteries such as lithium-ion and solid-state batteries. Lithium-ion batteries are now essential for smartphones, laptops, and electric vehicles due to their high energy density and long cycle life. Supercapacitors and redox flow batteries are emerging as efficient storage solutions for renewable energy systems like solar and wind power. These technologies are critical in achieving global goals for sustainable energy and reducing dependence on fossil fuels.

In the field of environmental protection, electrochemical methods are used for water purification, waste treatment, and monitoring pollution. Fuel cells, which convert hydrogen and oxygen into water while producing electricity, represent one of the cleanest

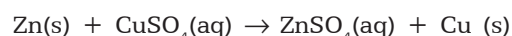
energy technologies of the future. Similarly, research in bioelectrochemical cells aims to use microorganisms to generate power from organic waste, opening new pathways for green energy.

Electrochemical cells illustrate the powerful connection between chemistry and electricity. From the Voltaic pile invented by Alessandro Volta in 1800 to today's high-performance lithium and hydrogen fuel cells, their evolution has transformed modern life. As research continues, electrochemical cells will remain central to innovations in energy storage, sustainable development, and environmental protection, shaping a cleaner and more efficient future for humanity.

1. **Galvanic Cell (Voltaic cell)** : It is a device in which a spontaneous chemical reaction generates an electric current i.e., it converts chemical energy into electrical energy. It is commonly known as a battery.
2. **Electrolytic cell** : It is a device in which an electric current from an external source drives a non-spontaneous reaction i.e., it converts electrical energy into chemical energy.

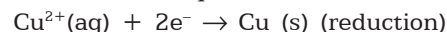
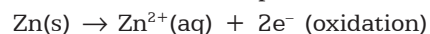
Galvanic cell

We know that when a zinc metal strip is placed in a copper sulphate solution, the blue colour of the solution fades and the copper is deposited on the zinc strip as red – brown crust due to the following spontaneous chemical reaction.



The energy produced in the above reaction is lost to the surroundings as heat.

In the above redox reaction, Zinc is oxidised to Zn^{2+} ions and the Cu^{2+} ions are reduced to metallic copper. The half reactions are represented as below.



If we perform the above two half reactions separately in an apparatus as shown in figure, some of the energy produced in the reaction will be converted into electrical energy. Let us understand the function of a galvanic cell by considering Daniel cell as an example. It uses the above reaction for generation of electrical energy.

The separation of half reaction is the basis for the construction of Daniel cell. It consists of two half cells.

Oxidation half cell

A metallic zinc strip that dips into an aqueous solution of zinc sulphate taken in a beaker, as shown in Figure.

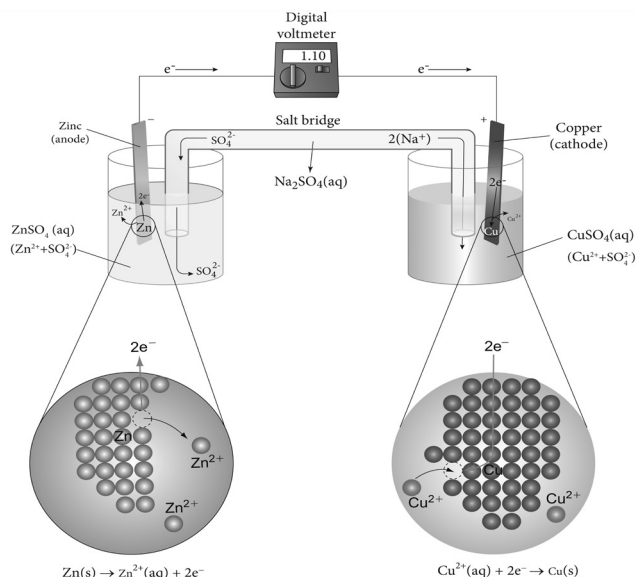
Reduction half cell

A copper strip that dips into an aqueous solution of copper sulphate taken in a beaker, as shown in Figure.

Joining the half cells

The zinc and copper strips are externally connected using a wire through a switch (k) and a load (example: volt meter). The electrolytic solution present in the cathodic and anodic compartment are connected using an inverted U tube containing agar-agar gel mixed with an inert electrolytes such as KCl, Na_2SO_4 etc., The ions of inert electrolyte do not react with other ions present in the half cells and they are not either oxidised (or) reduced at the electrodes. The solution in the salt bridge cannot get poured out, but through which the ions can move into (or) out of the half cells.

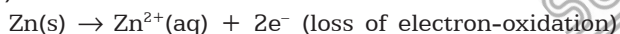
When the switch (k) closes the circuit, the electrons flows from zinc strip to copper strip. This is due to the following redox reactions which are taking place at the respective electrodes.



Daniel cell

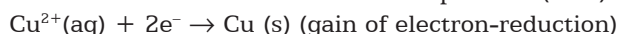
Anodic oxidation

The electrode at which the oxidation occurs is called the anode. In Daniel cell, the oxidation take place at zinc electrode, i.e., zinc is oxidised to Zn^{2+} ions by loosing its electrons. The Zn^{2+} ions enter the solution and the electrons enter the zinc metal, then flow through the external wire and then enter the copper strip. Electrons are liberated at zinc electrode and hence it is negative (-ve).



Cathodic reduction

As discussed earlier, the electrons flow through the circuit from zinc to copper, where the Cu^{2+} ions in the solution accept the electrons, get reduced to copper and the same get deposited on the electrode. Here, the electrons are consumed and hence it is positive (+ve).



Salt bridge

The electrolytes present in two half cells are connected using a salt bridge. We have learnt that the

anodic oxidation of zinc electrodes results in the increase in concentration of Zn^{2+} in solution. i.e., the solution contains more number of Zn^{2+} ions as compared to SO_4^{2-} and hence the solution in the anodic compartment would become positively charged. Similarly, the solution in the cathodic compartment would become negatively charged as the Cu^{2+} ions are reduced to copper i.e., the cathodic solution contain more number of SO_4^{2-} ions compared to Cu^{2+} .

To maintain the electrical neutrality in both the compartments, the non reactive anions Cl^- (from KCl taken in the salt bridge) move from the salt bridge and enter into the anodic compartment, at the same time some of the K^+ ions move from the salt bridge into the cathodic compartment.

Completion of circuit

Electrons flow from the negatively charged zinc anode into the positively charged copper cathode through the external wire, at the same time, anions move towards anode and cations are move towards the cathode compartment. This completes the circuit.

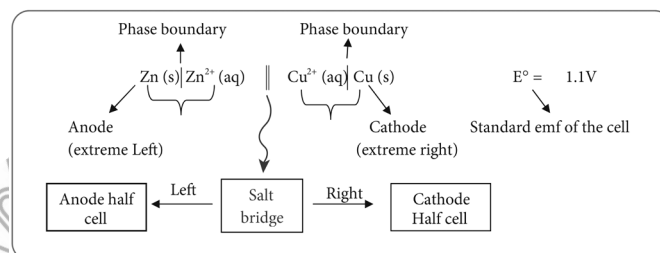
Consumption of Electrodes

As the Daniel cell operates, the mass of zinc electrode gradually decreases while the mass of the copper electrode increases and hence the cell will function until the entire metallic zinc electrode is converted in to Zn^{2+} or the entire Cu^{2+} ions are converted in to metallic copper.

Unlike Daniel cell, in certain cases, the reactants (or) products cannot serve as electrodes and in such cases inert electrode such as graphite (or) platinum is used which conducts current in the external circuit.

Galvanic cell notation

The galvanic cell is represented by a cell diagram, for example, Daniel cell is represented as



In the above notation, a single vertical bar (|) represents a phase boundary and the double vertical bar (||) represents the salt bridge.

- ➡ The anode half cell is written on the left side of the salt bridge and the cathode half cell on the right side.
- ➡ The anode and cathode are written on the extreme left and extreme right, respectively.
- ➡ The emf of the cell is written on the right side after cell diagram.

emf of a Cell

We have learnt that when two half cells of a Daniel cell are connected, a spontaneous redox reaction will

ANTIBIOTICS

- ➡ Antibiotics are powerful chemical substances that destroy or inhibit the growth of microorganisms, particularly bacteria, without significantly harming human or animal cells. They have been one of the most revolutionary discoveries in medical science, transforming healthcare and drastically reducing deaths from infectious diseases. The word “antibiotic” literally means “against life,” referring to their ability to combat harmful microbes.
- ➡ The history of antibiotics began with Alexander Fleming’s discovery of penicillin in 1928, when he observed that a mold, *Penicillium notatum*, inhibited bacterial growth. This accidental discovery paved the way for the antibiotic era, especially during World War II, when penicillin was mass-produced and saved countless lives. Later, scientists such as Selman Waksman discovered other antibiotics, including streptomycin, the first effective treatment for tuberculosis. Since then, hundreds of antibiotics have been developed, either naturally derived from microorganisms or synthetically produced in laboratories.
- ➡ Antibiotics work through different mechanisms of action. Some destroy the bacterial cell wall (e.g., penicillin, cephalosporins), others interfere with protein synthesis (e.g., tetracyclines, aminoglycosides), DNA replication (e.g., quinolones), or metabolic processes (e.g., sulfonamides). Based on their activity, antibiotics can be bactericidal (kill bacteria) or bacteriostatic (inhibit their growth). They are broadly classified into groups such as beta-lactams, macrolides, aminoglycosides, fluoroquinolones, and tetracyclines.
- ➡ The role of antibiotics in modern medicine is immense. They are used to treat a wide range of infections such as pneumonia, tuberculosis, meningitis, sepsis, urinary tract infections, and wound infections. Moreover, antibiotics have made complex medical procedures possible. In surgery, chemotherapy, and organ transplants, antibiotics prevent and control secondary infections, protecting patients whose immune systems are weakened. Veterinary medicine also relies on antibiotics to treat infections in animals and prevent the spread of diseases in livestock.
- ➡ However, one of the most serious global challenges today is antibiotic resistance. When antibiotics are overused or misused—such as taking them without prescription, not completing a course, or using them for viral infections like the common cold—bacteria evolve mechanisms to survive these drugs. Resistant strains like MRSA (Methicillin-Resistant

Staphylococcus aureus) and multi-drug resistant tuberculosis (MDR-TB) have emerged, making infections harder and costlier to treat. The World Health Organization (WHO) warns that antibiotic resistance is one of the biggest threats to global health, food security, and development.

- ➡ To combat this problem, global efforts focus on rational antibiotic use, public awareness, strict regulation, and research into new antimicrobial agents. Scientists are exploring next-generation antibiotics, phage therapy, and nanotechnology-based drug delivery systems to overcome resistance. Governments and healthcare systems are promoting antibiotic stewardship programs to ensure these medicines are prescribed only when truly necessary.
- ➡ In conclusion, antibiotics are among the greatest achievements of modern science, forming the cornerstone of infection control and modern medicine. Yet, their power comes with responsibility. To preserve their effectiveness, humanity must use them wisely, encourage ongoing research, and maintain strong public health policies. The future of antibiotics depends on a balance between innovation and awareness—ensuring these “miracle drugs” continue to save lives for generations to come.

Examples of Common Antibiotics (with Types and Uses):

Penicillin Group -

- ➡ **Examples:** Penicillin G, Amoxicillin, Ampicillin.
- ➡ **Action:** Inhibits bacterial cell wall synthesis (bactericidal).
- ➡ **Uses:** Treats throat infections, pneumonia, skin infections, and syphilis.
- ➡ **Discovered by:** Alexander Fleming (1928).

Cephalosporins -

- ➡ **Examples:** Cephalexin, Ceftriaxone, Cefotaxime.
- ➡ **Action:** Similar to penicillin; broad-spectrum against gram-positive and gram-negative bacteria.
- ➡ **Uses:** Respiratory tract infections, urinary tract infections (UTIs), and meningitis.

Tetracyclines -

- ➡ **Examples:** Tetracycline, Doxycycline, Minocycline.
- ➡ **Action:** Inhibit protein synthesis (bacteriostatic).
- ➡ **Uses:** Acne, respiratory infections, and certain sexually transmitted infections (STIs).

Macrolides -

- ➡ **Examples:** Erythromycin, Azithromycin, Clarithromycin.
- ➡ **Action:** Block bacterial protein synthesis.

- **Uses:** Throat infections, pneumonia, and skin infections, especially in penicillin-allergic patients.

Aminoglycosides -

- **Examples:** Gentamicin, Streptomycin, Amikacin.
- **Action:** Inhibit bacterial protein synthesis (bactericidal).
- **Uses:** Severe infections like sepsis, tuberculosis, and hospital-acquired infections.

Fluoroquinolones -

- **Examples:** Ciprofloxacin, Levofloxacin, Ofloxacin.
- **Action:** Interfere with bacterial DNA replication.
- **Uses:** UTIs, gastrointestinal infections, and respiratory infections.

Sulfonamides (Sulfa Drugs) -

- **Examples:** Sulfamethoxazole, Trimethoprim (combined as Co-trimoxazole).

- **Action:** Inhibit bacterial folic acid synthesis.
- **Uses:** UTIs, bronchitis, and ear infections.

Carbapenems -

- **Examples:** Imipenem, Meropenem.
- **Action:** Broad-spectrum; inhibit cell wall synthesis.
- **Uses:** Serious hospital-acquired infections and resistant bacterial strains.

Chloramphenicol -

- **Action:** Inhibits protein synthesis.
- **Uses:** Typhoid fever, meningitis (used with caution due to side effects).

Vancomycin -

- **Action:** Inhibits bacterial cell wall synthesis.
- **Uses:** Effective against MRSA and other resistant gram-positive infections.

BIOTECHNOLOGY AND APPLICATIONS

- The term biotechnology was coined by Karl Ereky, a Hungarian Engineer in 1919 and has been extended to include any process in which organisms, tissues, cells, organelles or isolated molecules such as enzymes are used to convert biological or other raw materials to products of greater value.
- Modern biotechnology embraces all methods of genetic modification by recombinant DNA and cell fusion technology. The major focus of biotechnology is on
- Fermentation for production of acids, enzymes, alcohols, antibiotics, fine chemicals, vitamins and toxins
 - Biomass for bulk production of single cell protein, alcohol, and biofuel
 - Enzymes as biosensors, in processing industry
 - Biofuels for production of hydrogen, alcohol, methane
 - Microbial inoculants as biofertiliser, and nitrogen fixers
 - Plant and animal cell culture for production of secondary metabolites, monoclonal antibodies
 - Recombinant DNA technology for production of fine chemicals, enzymes, vaccines, growth hormones, antibiotics, and interferon

COMPONENTS OF BIOTECHNOLOGY

Fermentation

- The word fermentation is derived from the Latin verb 'fervere' which means 'to boil'. Fermentation refers to the metabolic process in which organic molecules (normally glucose) are converted into acids, gases, or alcohol in the absence of oxygen or any electron transport chain. The study of

fermentation, its practical uses is called zymology and originated in 1856, when French chemist Louis Pasteur demonstrated that fermentation was caused by yeast. Fermentation occurs in certain types of bacteria and fungi that require an oxygen-free environment to live. The processes of fermentation are valuable to the food and beverage industries, with the conversion of sugar into ethanol to produce alcoholic beverages, the release of CO₂ by yeast used in the leavening of bread, and with the production of organic acids to preserve and flavor vegetables and dairy products.

Bioreactor (Fermentor)

- Bioreactor (Fermentor) is a vessel or a container that is designed in such a way that it can provide an optimum environment in which microorganisms or their enzymes interact with a substrate to produce the required product. In the bioreactor aeration, agitation, temperature and pH are controlled. Fermentation involves two process namely upstream and downstream process.

Procedure of Fermentation

- Depending upon the type of product, bioreactor is selected.
- A suitable substrate in liquid medium is added at a specific temperature, pH and then diluted.
- The organism (microbe, animal/plant cell, sub-cellular organelle or enzyme) is added to it.
- Then it is incubated at a specific temperature for the specified time.
- The incubation may either be aerobic or anaerobic.
- Withdrawal of product using downstream processing methods

Application of fermentation in industries

Fermentation has industrial application such as:

1. Microbial biomass production

- Microbial cells (biomass) like algae, bacteria, yeast, fungi are grown, dried and used as source of a complete protein called 'single cell protein (SCP)' which serves as human food or animal feed.

2. Microbial metabolites

Microbes produce compounds that are very useful to man and animals. These compounds called metabolites, can be grouped into two categories:

- Primary metabolites** : Metabolites produced for the maintenance of life process of microbes are known as primary metabolites Eg. Ethanol, citric acid, lactic acid, acetic acid.
- Secondary metabolites** : Secondary metabolites are those which are not required for the vital life process of microbes, but have value added nature, this includes antibiotics e.g-Amphotericin-B (Streptomyces nodosus), Penicillin (Penicillium chrysogenum) Streptomycin (S. grises) , Tetracycline (S. aureofacins), alkaloids, toxic pigments, vitamins etc.

3. Microbial enzymes

- When microbes are cultured, they secrete some enzymes into the growth media. These enzymes are industrially used in detergents, food processing, brewing and pharmaceuticals. Eg. protease, amylase, isomerase, and lipase.

4. Bioconversion, biotransformation or modification of the substrate

- The fermenting microbes have the capacity to produce valuable products, eg. conversion of ethanol to acetic acid (vinegar), isopropanol to acetone, sorbitol to sorbose (this is used in the manufacture of vitamin C), sterols to steroids.

Single Cell Protein (SCP)

- Single cell proteins are dried cells of microorganism that are used as protein supplement in human foods or animal feeds. Single Cell Protein (SCP) offers an unconventional but plausible solution to protein deficiency faced by the entire humanity. Although single cell protein has high nutritive value due to its higher protein, vitamin, essential amino acids and lipid content, there are doubts on whether it could replace conventional protein sources due to its high nucleic acid content and slower in digestibility. Microorganisms used for the production of Single Cell Protein are as follows:
- Bacteria - Methylophilus methylotrophus, Cellulomonas, Alcaligenes
- Fungi - Agaricus campestris, Saccharomyces cerevisiae (yeast), Candida utilis

- Algae - Spirulina, Chlorella, Chlamydomonas

The single cell protein forms an important source of food because of their protein content, carbohydrates, fats, vitamins and minerals. It is used by Astronauts and Antarctica expedition scientists.

Spirulina can be grown easily on materials like waste water from potato processing plants (containing starch), straw, molasses, animal manure and even sewage, to produce large quantities and can serve as food rich in protein, minerals, fats, carbohydrate and vitamins. Such utilization also reduces environmental pollution. 250 g of Methylophilus methylotrophus, with a high rate of biomass production and growth, can be expected to produce 25 tonnes of protein.

Applications of Single-Cell Protein

- It is used as protein supplement
- It is used in cosmetics products for healthy hair and skin
- It is used as the excellent source of protein for feeding cattle, birds, fishes etc.
- It is used in food industry as aroma carriers, vitamin carrier, emulsifying agents to improve the nutritive value of baked products, in soups, in ready-to-serve-meals, in diet recipes
- It is used in industries like paper processing, leather processing as foam stabilizers.

ADVANCEMENTS IN MODERN BIOTECHNOLOGY

Modern biotechnology embraces all the genetic manipulations, protoplasmic fusion techniques and the improvements made in the old biotechnological processes. Some of the major advancements in modern biotechnology are described below:-

Genetic Engineering

- Genetic engineering or recombinant DNA technology or gene cloning is a collective term that includes different experimental protocols resulting in the modification and transfer of DNA from one organism to another.
- Conventional recombination involves exchange or recombination of genes between homologous chromosomes during meiosis. Recombination carried out artificially using modern technology is called recombinant DNA technology (r-DNA technology). It is also known as gene manipulation technique. This technique involves the transfer of DNA coding for a specific gene from one organism into another organism using specific agents like vectors or using instruments like electroporation, gene gun, liposome mediated, chemical mediated transfers and microinjection.

PCR : Polymerase Chain Reaction is a common laboratory technique used to make copies (millions) of a particular region of DNA.

Virus-free plants

The field grown plants like perennial crops, usually are infected by variety of pathogens like fungi, bacteria, mycoplasma, viruses which cause considerable economic losses. Chemical methods can be used to control fungal and bacterial pathogens, but not viruses generally.

Shoot meristem tip culture is the method to produce virus-free plants, because the shoot meristem tip is always free from viruses.

Conservation of plant genetic resources**Germplasm Conservation**

- Germplasm conservation refers to the conservation of living genetic resources like pollen, seeds or tissue of plant material maintained for the purpose of selective plant breeding, preservation in live condition and used for many research works.
- Germplasm conservation resources is a part of collection of seeds and pollen that are stored in seed or pollen banks, so as to maintain their viability and fertility for any later use such as hybridization

and crop improvement. Germplasm conservation may also involve a gene bank, DNA bank of elite breeding lines of plant resources for the maintenance of biological diversity and also for food security.

Cryopreservation (-195°C)

- Cryopreservation, also known as Cryo-conservation, is a process by which protoplasts, cells, tissues, organelles, organs, extracellular matrix, enzymes or any other biological materials are subjected to preservation by cooling to very low temperature of -195°C using liquid nitrogen. At this extreme low temperature any enzymatic or chemical activity of the biological material will be totally stopped and this leads to preservation of material in dormant status. Later these materials can be activated by bringing to room temperature slowly for any experimental work.
- Protective agents like dimethyl sulphoxide, glycerol or sucrose are added before cryopreservation process. These protective agents are called cryoprotectants, since they protect the cells, or tissues from the stress of freezing temperature.

OTHER APPLICATIONS OF BIOTECHNOLOGY

- Genetic engineering involves the manipulation of DNA and naturally occurring processes such as protein synthesis for a wide range of applications including the production of therapeutically important proteins. This also involves extracting a gene from one organism and transferring it to the DNA of another organism, of the same or another species. The DNA produced in this way is referred to as recombinant DNA (rDNA) and this technique as recombinant DNA technology. All these are part of the broad field biotechnology which can be defined as the applications of scientific and engineering principles to the processing of material by biological agents to provide goods and services.
- Recombinant DNA technology has led to the large scale production of various hormones and proteins of therapeutic use.

Applications in Medicine**Recombinant Human Insulin**

- The Human insulin is synthesized by the β cells of Islets of Langerhans in the pancreas. It is formed of 51 aminoacids which are arranged in two polypeptide chains, A and B. The polypeptide chain A has 21 amino acids while the polypeptide chain B has 30 amino acids. Both A and B chains are attached together by disulphide bonds. Insulin controls the levels of glucose in blood. It facilitates the cellular uptake and utilization of glucose for the release of energy. Deficiency of insulin leads to diabetes mellitus which is characterized by increased blood glucose concentration and a complex of symptoms which may lead to death, if untreated. A continuous

program of insulin dependence is required to treat this deficiency.

- Insulin was the first ever pharmaceutical product of recombinant DNA technology administered to humans. The approval to use recombinant insulin for diabetes mellitus was given in 1982. In 1986 human insulin was marketed under the trade name Humulin.

Human alpha lactalbumin

Alpha lactalbumin is a protein composed of 123 amino acids and 4 disulphide bridges, with a molecular weight of 14178 Da. In human milk, α lactalbumin is the most abundant protein comprising 25% of total protein found in human milk. It is synthesized by the mammary glands. α lactalbumin binds calcium and zinc ions and possesses bactericidal and anti tumour activities.

Improvement of the nutritional value of cow's milk with transgenic expression of recombinant human alpha lactalbumin has been attempted. Healthy transgenic cows were produced by somatic nuclear transfer, in which expression of upto 1.55g/L of recombinant human alpha lactalbumin was achieved. Similarly transgenic goats were also produced, in which the expression of Human alpha lactalbumin was about 0.1 to 0.9mg/mL.

Interferons

Interferons are proteinaceous, antiviral, species specific substances produced by mammalian cells when infected with viruses. Interferons were discovered by Alick Isaacs and Jean Lindemann in 1957. Based on the structure of interferons they are classified as α , β and γ interferons. They stimulate the cellular DNA to